

①

THEORETICAL INVESTIGATIONS FOR IMPROVED DECOMPRESSION PROCEDURES

AD-A151 985

R.D. Vann, Ph.D.
P.B. Bennett, Ph.D., D.Sc.

Department of Anesthesiology and F.G. Hall Laboratory
Duke University Medical Center
Durham, NC 27710

Final Report on Office of Naval Research Contract
N00014-84-C-0152

20000807034

February 13, 1985

DTIC FILE COPY

DTIC
ELECTE
MAR 26 1985
S D E

This document has been approved
for release under its
original classification

Reproduced From
Best Available Copy

85 03 01 052

Research was conducted and reported on this past year in areas including basic decompression mechanisms, bubble formation, inert gas exchange, no-stop diving, saturation diving, space decompression, and CNS oxygen toxicity. The reports of this research are summarized below and are attached in an appendix.

In "Another view of the fundamental issues for table development" (Vann 1984b) presented at the Decompression Symposium during the 1984 UMS Meeting, the mechanisms of bubble formation and inert gas exchange (both dissolved and undissolved) were reviewed. These mechanisms were applied to the calculation of decompression schedules where bubble volume is considered the agent responsible for decompression sickness. This model was used to illustrate the effects of exercise on decompression sickness and decompression time. A series of dive trials which explored the effect of exercise was described.

A poster session at the 1984 UMS Meeting, "Bubble formation in animals: a crevice gas nucleus with zero volume" (Vann and Feezor 1984), described a hypothetical mechanism whereby bubbles could form in tissue in the absence of undissolved gas. This mechanism is a consequence of hydrogen bonding which results in the self-assembly of gas nuclei in tissue just as micelles are self-assembling in an aqueous solution of lipids. Gas nuclei are created at the interface of a hydrophobic surface (surrounded by a hydrophilic surface) and an aqueous medium. The state of lowest free energy occurs when a layer of gas is adsorbed at this interface.

Bubble formation in mammary implants was studied experimentally, and an abstract, "Mammary implants and diving" (Vann, Georgiade, and Riefkohl 1985), was submitted for the 1985 UMS Meeting. This study was prompted by inquiries from sport divers. The conclusions were that bubble formation does occur to a limited degree after simulated sport diving profiles but should not represent a health hazard. Saturation diving with mammary implants should be avoided, however, as more extensive bubble formation can occur.

The results of an experimental study of inert gas exchange, "Decompression induced nitrogen elimination" (Dick, Vann, Mebane, and Feezor 1984), were published in Undersea Biomedical Research. This study introduced a new experimental technique by which nitrogen elimination measurements could be made at the end of a dive without using oxygen breathing. Oxygen breathing obscures the natural nitrogen elimination which occurs in air breathing divers. Elimination measurements were made after standard USN no-stop air dives with both rest and exercise. Significantly more nitrogen was eliminated after exercising dives, but there was a wide variation under all conditions. These results suggest that while whole body inert gas exchange measurements are useful for studying the influence of environmental and physiological factors, they are of less value for predicting the risk of marginal decompression sickness.

An analytical study, "DCS risk and no-stop diving" (Vann 1985c) was submitted for the Decompression Symposium at the 1985

UMS Meeting. This study applied the likelihood method (Weathersby, Homer, and Flynn 1984) to 2,020 no-stop nitrogen-oxygen dives and estimated the risk of decompression sickness for the USN no-stop dive exposure limits and a more conservative set of limits for sport divers. The results suggest that a finite risk of decompression sickness exists for any no-stop dive of useful length. This emphasizes the importance of planning for emergencies before they occur.

A series of reports on saturation decompression were presented or published. "Decompression from a deep nitrogen/oxygen saturation dive - a case report" (Barry, Vann, Youngblood, Peterson, and Bennett 1984) was published in Undersea Biomedical Research and described a dive in which there were 5 cases of decompression sickness in 10 divers. One of these occurred in a commercial aircraft 68 hrs after surfacing. The influence of saturation depth on the risk of decompression sickness was analyzed, and it was concluded that the risk is greater for deeper dives.

A paper, "Decompression from saturation dives" (Vann 1984a), was presented at a Decompression Symposium of the 1984 Canadian Offshore Technology Conference. This paper addressed the problem of decompression from both nitrogen-oxygen and helium-oxygen saturation dives. Dive results were analyzed using the equation

$$\text{Rate} = K * \text{PIO}_2 \quad (1)$$

in which the ascent rate is proportional to the inspired oxygen partial pressure, and the proportionality constant K decreases with increasing saturation depth. Decompression schedules were estimated for nitrogen-oxygen dives with depths of 200 FSW (61 MSW) to 40 FSW (12 MSW) and for helium-oxygen dives with depths of 2250 FSW (686 MSW) to 100 FSW (30 MSW).

A paper, "Air and NITROX saturation decompression: a report of 4 schedules and 77 subjects" (Eckenhoff and Vann 1985) was accepted for publication by Undersea Biomedical Research. This paper is largely a description of experimental results including doppler bubble detection determinations on 2 schedules. These 2 schedules were calculated with equation (1).

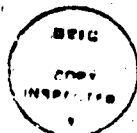
The analysis of nitrogen-oxygen saturation decompression schedules was extended in "A comprehensive strategy for saturation decompression with nitrogen-oxygen" (Vann 1985a) by the use of likelihood (Weathersby, Homer, and Flynn 1984). A decompression model was developed assuming that bubble growth is proportional to ascent rate and resolution is proportional to inspired oxygen partial pressure. This model is consistent with equation (1) and with the observation that slower ascent rates are required for deeper dives. The risks of decompression sickness were evaluated in an analysis of 21 saturation decompression schedules. Decompression schedules were estimated for dives to various depths and with various gas mixes. Doppler bubble measurement data were reviewed to assess the usefulness of doppler in saturation diving. It was concluded that decompression sickness was more likely at the higher bubble grades

for sub-saturation decompression, saturation decompression, and altitude exposure and that doppler bubble measurements could be used profitably for the development and evaluation of saturation decompression schedules.

An abstract, "Selection of space craft and space suit atmospheres" (Vann and Torre-Bueno 1984a), was presented at the 1984 UMS Meeting. A paper on the same topic, "A theoretical method for selecting space craft and space suit atmospheres" (Vann and Torre-Bueno 1984b), was published in Aviation, Space, and Environmental Medicine. These reports discussed the use of a decompression model in which bubble volume is the cause of decompression sickness. The model was applied to the prediction of decompression procedures for the space environment and to the analysis of procedures which have been tested for use in the Space Shuttle.

An abstract, "CNS oxygen toxicity risk" (Vann 1985b) was submitted for the 1985 UMS Meeting. This abstract reports on analysis of 589 man-exposures on 100% oxygen using likelihood (Weathersby, Homer, and Flynn 1984) and a model of oxygen toxicity based upon the production and elimination of free oxygen radicals. The risks of oxygen toxicity were estimated for the old and new U.S. Navy oxygen exposure limits. These estimates suggest that the risk of toxicity increases slowly with exposure time and that there is a pressure below which essentially no risk exists.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	<i>per</i>
By	
Distribution/	
Availability Codes	
Avail and/or	
Dist	Special
A-1	



References

- Barry, P.D., R.D. Vann, D.A. Youngblood, R.E. Peterson, and P.B. Bennett. 1984. Decompression from a deep nitrogen/oxygen saturation dive: a case report. *Undersea Biomed. Res.* 11(4): 387-393.
- Dick, A.P., R.D. Vann, G.Y. Mebano, and M.D. Feezor. 1984. Decompression induced nitrogen elimination. *Undersea Biomed. Res.* 11(4): 369-380.
- Eckenoff, R.G. and R.D. Vann. 1985. Air and nitrogen/oxygen saturation decompression: a report of 4 schedules and 77 subjects. *Undersea Biomed. Res.* 12(1): In press.
- Vann, R.D. 1984a. Decompression after saturation diving. In: Proceedings of the 3rd Annual Canadian Ocean Technology Congress. March 21-23. Toronto. Pp. 175-188.
- Vann, R.D. 1984b. Another view of the fundamental issues for table development. Symposium on "Decompression Tables: underlying assumptions." San Antonio, Texas, May 29. *Undersea Biomed. Res.* 11(3): 333-336.
- Vann, R.D. 1985a. A comprehensive strategy for saturation decompression with nitrogen-oxygen. In: Workshop on Decompression from NITROX Saturation Diving. Undersea Medical Society and NOAA. Institute for Environmental Medicine, University of Pennsylvania. January 8-9.
- Vann, R.D. 1985b. CNS oxygen toxicity risk. Abstract submitted for 1985 Undersea Medical Society / Hyperbaric Oxygen Conference Annual Meeting. Long Beach, CA. June 11-14.
- Vann, R.D. 1985c. DCS risk and no-stop air diving. To be presented during the Decompression Sickness Symposium at the 1985 Undersea Medical Society / Hyperbaric Oxygen Conference Annual Meeting. Long Beach, CA. June 11-14.
- Vann, R.D. and M.D. Feezor. 1984. Bubble formation in animals: a crevice gas nucleus with zero volume. *Undersea Biomed. Res.* 11(1, Suppl.): Abstract 4.
- Vann, R.D., G.S. Georgiade, and R.E. Riefkohl. 1985. Mammary implants and diving. Abstract submitted for 1985 Undersea Medical Society / Hyperbaric Oxygen Conference Annual Meeting. Long Beach, CA. June 11-14.
- Vann, R.D. and J.R. Torre-Bueno. 1984a. Selection of space craft and space suit atmospheres. *Undersea Biomed. Res.* 1(11, Suppl.): Abstract 9.
- Vann, R.D. and J.R. Torre-Bueno. 1984b. A theoretical method for selecting space craft and space suit atmospheres. *Av., Space, Environ. Med.* 55(12): 1097-2002.

Weathersby, P.K., L.D. Homer, and E.T. Flynn. 1984. On the likelihood of decompression sickness. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 57(3): 815-825.

END

FILMED

5-85

DTIC